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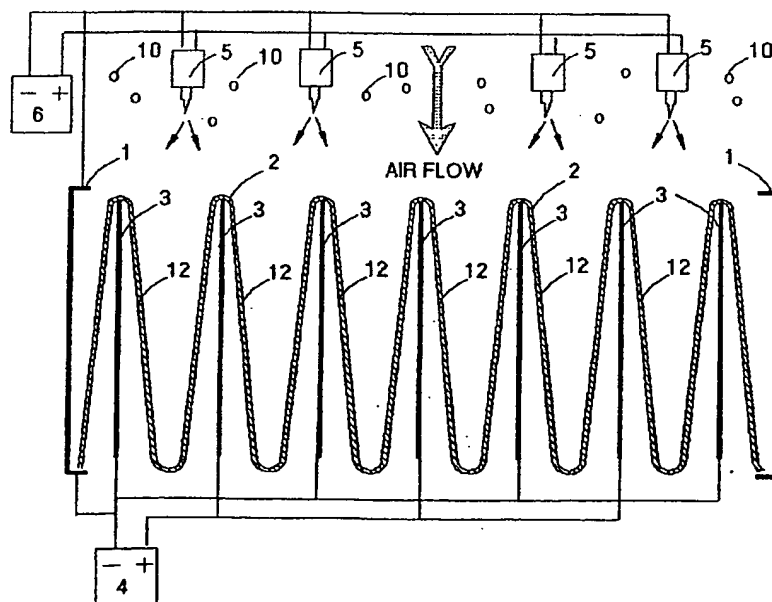
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(54) Title: ELECTRONIC POLARIZED AIR FILTER



(57) Abstract: An electrostatic precipitator type filter is combined with replaceable, polarizable trapping media. In one aspect of the invention, the media is fitted between polarizing plates. In another aspect, the media is coated in sections to form a conductive surface which serve as the charged plates of the precipitator. Ionization is preferably provided by a series of ionizing elements such as ionizing needles.

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TITLE: ELECTRONIC POLARIZED AIR FILTER

FIELD OF THE INVENTION

This invention relates to air filters. In particular, it relates to electronically-enhanced filters that include a trapping medium.

BACKGROUND TO THE INVENTION

Precipitator-type air filters of the type depicted in U.S. Pat. No. 2,593,869 to Fruth (1952) operate by first ionizing particulate-carrying air to charge dust contained therein, and then pass the air between oppositely charged, end-on aligned parallel plates to which the dust adheres. Such precipitating air cleaners are highly efficient when the plates are initially clean. However, performance drops off as the plates become covered with collected dust. Hence, regular cleaning is required to maintain efficiency. This cleaning operation for precipitator-type air cleaners is awkward and costly to effect.

An advantage of filters of the trapping media type is that such media may be readily removed and replaced once they are filled with dust.

It is known that in trapping airborne particles in disposable filter media such as fibrous matrices of glass, wool and the like, the trapping capacity of such filter media can be enhanced by ionizing the air, and charging the dust therein, before it enters the filter medium. U.S. Pat. Nos. 3,706,182 to Sargent (1972), and 4,244,710 to Burger (1981) both depict such an arrangement. In both of these references, ions are introduced into the airflow stream by ion emitters

positioned at an upstream location in the airflow, at a spaced distance from the filter medium that is intended to trap and remove charged particles from the airflow. Prior inventions by the present inventor also rely on the upstream release of ions
5 into an air flow as presented in U.S. Pat. Nos. 5,518,531 (1996) and 6,077,334 (June 20 2000).

It is also known that the trapping of dust particles, especially charged dust particles, can be enhanced by using as a trapping medium an air-permeable matrix of non-
10 conducting, polarizable material. Local dipoles formed within such medium help trap and bind dust particles. An example of a prior art reference based on this principle is U.S. Patent No. 4,549,887 by the present inventor.

The present invention makes use of the airflow-
15 aligned, charged parallel plate principle and, optionally, the ionization principle in conjunction with polarized media to provide an improved performance filter.

The invention in its general form will first be described, and then its implementation in terms of specific
20 embodiments will be detailed with reference to the drawings following hereafter. These embodiments are intended to demonstrate the principle of the invention, and the manner of its implementation. The invention in its broadest and more specific forms will then be further described, and defined, in
25 each of the individual claims which conclude this Specification.

SUMMARY OF THE INVENTION

In one aspect of the invention a series of generally parallel, alternately charged metal electrodes, aligned to
30 receive air-flow edge-on, are used as polarizing electrodes to

polarize trapping media contained between electrodes. The trapping medium may be in the form of a fibrous dielectric pad and/or may comprise pleated panels of air permeable trapping material. The electrodes are preferably aligned parallel to the airflow (although this is optional), to provide a polarizing, transverse field through the trapping medium. The polarizing electrodes may be in the form of plates between which the trapping media is placed. Alternately, polarizing electrodes may be formed right on the trapping media surface as by sheets of conductive screening or fabric. This can also be effected by rendering surface segments of the trapping media conducting as well as by providing an air permeable conductive layer laid over such surfaces. The electrodes and trapping media may conveniently be formatted as a cartridge for ready removal and replacement.

In all of these variants, ionization may be provided upstream in the arriving airflow by a series of ionizing needles or other ionizing elements such as fine wires or conducting strings (c.f. U.S. Pat No. 5,573,577, Nov 12, 1996 by the present inventor). Such ionization charges dust particles in the air flow, enhancing further the trapping efficiency of the media present in the polarizing field formed between the oppositely charged polarizing electrodes.

Conductive surface portions may be formed on alternating sections of trapping medium constructed as a continuous surface folded into pleated panels by coating the medium with a conductive material, such as fine carbon or aluminum, preferably mixed with a binder. Conductive surfaces may also be formed by transferring conductive panels of conductive, porous (air-permeable) media to the trapping media as by an adhesive.

With trapping media contained between polarizing electrodes, a high potential voltage source is connected to provide a polarizing potential difference between consecutive electrodes. This potential difference not only tends to
5 polarize the intervening portions of the trapping medium but also creates an electrical potential field between the electrodes with a high field gradient. Dust particles, particularly charged dust particles, are drawn laterally in the air flow by this transverse field to contact and be
10 retrained in the trapping medium.

By these arrangements an improved air filter of increased efficiency and cost effectiveness is provided.

The foregoing summarizes the principal features of the invention and some of its optional aspects. The invention
15 may be further understood by the description of the preferred embodiments, in conjunction with the drawings, which now follow.

BRIEF DESCRIPTION OF THE DRAWINGS

20 Figure 1 shows a cross-sectional plan view of the air cleaner of the invention wherein polarizable, pleated filter media is disposed around charged polarizing plates;

Figure 2 shows a cross-sectional plan view of an alternate format air cleaner wherein the pleated filter
25 trapping medium is coated with conductive paint in strips and the strips are charged with high voltage of alternating polarity to form the polarizing electrodes;

Figure 3 is a plan view of the stretched-out pleated media of Figure 2 to demonstrate how the media is coated with
30 conductive paint in strips;

Figure 4 is a cross-sectional side view of the air cleaner assembly of Figure 1 mounted in an air duct with ionizing elements placed in front of the air filter;

Figure 5 is a cross-sectional rear end view of the
5 pleated media of Figure 2 compacted with glue-beads positioned to separate the folded pleats;

Figure 5A is a pictorial depiction of the pleated media of Figure 5 in transition as it is being folded to provide the compacted filter assembly of Figure 5;

10 Figure 6 is a cross-sectional plan view of the media of Figure 5 taken through the lines of glue beading showing the connection of the polarizing voltage source to the panel electrodes.

Figure 7 depicts an alternate arrangement wherein
15 multiple pieces of air-permeable, fibrous trapping media of dielectric material are sandwiched between conductive screens or plates;

Figure 8 shows a cross-sectional top view of the arrangement of Figure 7; and

20 Figure 9 shows two interrupted contacting bars for connecting the plates or screens of Figures 7 and 8 to a power supply.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In Figure 1 a casing 1 or frame 1 contains the
25 elements of the air cleaner. A permeable filter medium 2 of paper or the like which may be pleated is removably placed between and around a series of consecutive conductive plates 3 which serve as electrodes. While numerous plates are shown, the invention will work with two plates. It is highly
30 preferable, however, to employ many more plates.

Consecutive conductive plates 3 are respectively insulated from each other and are alternately connected to a high voltage power supply 4 which provides polarizing voltage of differential polarity between adjacent plates 3. 5 Permissibly, one set of plates 3 may be grounded. The object is to provide a strong electrostatic field with a steep gradient between the plates 3 and across the panels 12 of medium 2.

A set of ionizing elements 5 charge the dust 10 particles 10 arriving in front of the filter to increase its collecting efficiency. Ionizing elements 5 are supplied with high voltage from power supply 6.

As an alternative to a single pleated sheet, a polarizable fiber matrix or the like may be inserted between 15 the plates 3 as shown subsequently in Figure 7, below.

Figure 2 shows an alternate way of providing an electrostatic field across medium 2. A conducting coating 7 such as graphite or aluminum powder with a binder is applied to the surface of filter medium 2 in sections as shown in 20 Figure 3 to provide the electrodes. Conductivity may also be imparted to the panels by applying an infiltrating conductive liquid that leaves a conductive deposit e.g. colloidal carbon in a solution; or an air-permeable, conductive layer may be transferred to the sections of surfaces of the trapping medium 25 2 and held in place by an adhesive. Examples of such a layer include conductive fabrics such as copper-treated polypropylene fabric, conductive plastic grids and wire mesh screens of aluminum or the like.

While every other panel 19 is shown as having a 30 conductive surface 7 in Figure 2, coating may also be effected

intermittently so as to leave more than one intermediate panel 19 uncoated.

Metal rods 8 held by the frame 1 support medium 2 and at the same time make contact with the coated sections 7 on medium 2. Adjacent metal rods 8 are insulated from each other and they are respectively connected to the high voltage power supply 9 so as to be alternately charged with differing potentials. The conductive coatings 7, because they come in contact with metal rods 8, become charged with differing electrical potentials and thus produce a strong electrostatic field between them.

Figure 4 shows the air cleaner with its frame 1 installed into in a duct 11 of an air handling system. Ionizing elements 5 are optionally located upstream in the airflow 9. The frame 1 is readily removeable to permit servicing, and replacement of the filter medium 2.

Figures 5 and 6 show a pleated filter wherein the pleat panels 19 are separated by lengths of beads 13 of glue applied to the filter media 2 before it is pleated. The glue beads 13 keep the pleat panels 19 apart and at the same time make the filter self-supporting without any need for other structure, such as a screen.

The parts of the medium 2 that are coated, are charged to differential voltages as before by high voltage power supply 9. This voltage can be applied, for example, by contacting fingers respectively carried on two contactor bars to every other conductive surface 7. This type of filter can achieve efficiencies which are superior to a filter lacking the polarizing feature.

In Figures 7 and 8 conductive plates 7 or screens 20

are positioned to serve as electrodes between sections of fibrous trapping media 21. Electrode screens preferable of a flexible conductive plastic sheeting of the like are alternately charged by high voltage power supply 22 thus providing a strong electrostatic field between such screens which, in turn, polarizes sections of media 21 placed between the plates 2. The air-flow 9 enters the media 21 edge-on and flows through the body of the media 21. The extent of this flow, and trapping efficiency, can be controlled by varying the depth of the media 21.

The plates 7 or screens 20 need not be perfectly aligned, in parallel with the airflow 9. Such screens may be obliquely inclined to the direction of the entering airflow. In either case, the screens 20 receive the airflow 9 edge-on, as do the media sections 21. And the airflow 9 between the screens 20 passes in a direction which is parallel to the surface of the electrode (in the colloquial sense, and not parallel to the mathematical direction of such surface).

Figure 9 shows a method of connecting the plates or screens 20 to a high voltage power supply. Conductive rods 23 are insulated from the frame 1 of the filter and are connected to high voltage power supply 22. These rods 23 carry insulator sleeves 24 which have cut-outs 25 to expose the rods 23 at alternating intervals. Thus, when the filter of Figures 7 and 8 is pressed against the rods 23, one half of the screens 20 will make contact with one rod 23 and the other half with the other rod 23. In this way, the screens 20 in the filter are connected to alternate polarities of the power supply.

Operation of the air cleaner is as follows. Air flow 9 coming into the device as shown in Figure 4 first

passes by the ionizing elements 5 whereby the dust particles 10 acquire a charge. Further down the duct 11, the dust particles 10 encounter the strong, transverse polarizing electrostatic field present between the plates 3 or conducting surfaces 7 and are attracted towards such plates 3 or conducting surfaces 7 of the media 2. As the dust particles 10 move towards the plates 3, or surfaces 7, they become deposited on the media 2. To maintain the air cleaner in optimum operating condition, the media 2 is replaced with new, clean media 2 on a regular basis.

Optionally, the air cleaner may omit the ionizing elements 5 but the filter's efficiency will suffer.

Test were conducted with an air flow volume of around 1000 cfm (cubic feet per minute) with a pleated filter of about 6 inches in depth and an area of 20 x 24 inches, installed as in Figure 1. The results of these tests are useful for the comparison of relative performances, and are not to be taken as accurate in absolute terms. Particle counts were taken in household air with an INNOVATION 5000 particle count meter by Climet Corporation of California. Efficiencies were alternately calculated in accordance with the following formulae, repeatedly applied to sets of measurement data:

$$\text{where } \overline{us} = \frac{\overline{us_1} + \overline{us_2}}{2}$$

$$\text{Eff} = \frac{\overline{us} - \overline{ds}}{\overline{us}} \times 100$$

$$\text{where } \overline{ds} = \frac{ds_1 + ds_2}{2}$$

$$\text{Eff} = \frac{us_2 - \overline{ds}}{us_2} \times 100$$

On this basis, test results are shown in Tables 1 to 5 which now follow:

Table 1

5 Test with no ionizing elements and no voltage on the plates
(Particle Counts = PC)

	PC at	.3 mic	% Eff	.5 mic	%Eff	1 mic	%Eff	5 mic	%Eff
	us ₁	25096	15.00 (a)	5462	14.05	586	40.08	20	20.00
	ds ₁	21519	15.45 (b)	4580	10.21	376	37.67	16	40.00
10	us ₂	25535	15.47 (a)	5195	15.32	669	31.13	20	61.90
	ds ₂	21660		4749		458		8	
	us	25713		6022		661		22	
	Average Eff.		<u>15.31</u>		<u>13.19</u>		<u>36.29</u>		<u>40.63</u>

us = upstream

15

ds = downstream

Table 2

Test with negative ionizing elements and no voltage on the plates

	PC at	.3 mic	% Eff	.5 mic	%Eff	1 mic	%Eff	5 mic	%Eff
20	us	26078	26.39	9450	65.75	1307	68.28	42	86.52
	ds	19827	26.15	3422	65.95	448	70.19	6	81.91
	us	27789	23.37	10530	67.74	1518	72.84	47	81.51
	ds	21215	22.02	3748	68.60	457	73.58	11	77.78
	us	27583	26.05	12707	69.95	1847	75.12	72	73.08
25	ds	21804		4232		519		21	
	us	31390		15464		2325		84	
	Average Eff.		<u>24.80</u>		<u>67.60</u>				<u>80.16</u>

Table 3

Test on pleated filter without ionizing elements and positive 8KV on alternate plates with other plates grounded

	PC at	.3 mic	% Eff	.5 mic	%Eff	1 mic	%Eff	5 mic	%Eff
5	ds	1963	51.20	285	52.91	128	75.57	128	75.57
	us	4404	49.21	669	53.38	524	78.40	524	78.40
	ds	2335	47.89	345	51.36	128	74.43	128	74.43
	us	4791	49.87	811	52.67	661	71.96	661	71.96
	ds	2658		444		210		210	
10	us	5813		1065		837		837	
	Average Eff.		<u>49.54</u>		<u>52.58</u>		<u>75.09</u>		<u>75.09</u>

Table 4

Test with negative ionizing elements and negative 8KV on plates

	PC at	.3 mic	% Eff	.5 mic	%Eff	1 mic	%Eff	5 mic	%Eff
15	ds	771	68.30	114	67.13	72	61.75	6	86.11
	us	2711	68.59	432	67.40	332	59.96	54	89.60
	ds	938		170		182		9	
	us	3325		611		577		119	
20	Average Eff.		<u>68.44</u>		<u>67.27</u>		<u>60.85</u>		<u>87.85</u>

Table 5

Second test with two negative ionizing elements and negative 8KV on plates

	PC at	.3 mic	% Eff	.5 mic	%Eff	1 mic	%Eff	5 mic	%Eff
5	us	14236	66.61	1284	69.76	106	74.55	18	100.0
	ds	4894	69.75	417	68.42	28	74.12	0	96.43
	us	16941	70.44	1474	67.34	114	76.15	14	93.55
	ds	5355	68.65	514	66.04	31	76.71	1	88.24
	us	19288	67.34	1674	65.78	146	76.95	17	82.35
10	ds	6739	67.10	623	66.57	37	74.00	3	88.35
	us	21975	67.48	1967	67.20	175	73.46	17	88.24
	ds	7720		692		54			
	us	25509		2253		232			
	Average Eff.		<u>68.48</u>		<u>67.30</u>		<u>75.14</u>		<u>90.16</u>

15 The progressive improvements in measured efficiency are apparent, with maximum efficiency arising with the combination of upstream ionization and charged, polarized plates.

20 CONCLUSION

The foregoing has constituted a description of specific embodiments showing how the invention may be applied and put into use. These embodiments are only exemplary. The invention in its broadest, and more specific aspects, is
25 further described and defined in the claims which now follow.

These claims, and the language used therein, are to be understood in terms of the variants of the invention which have been described. They are not to be restricted to such variants, but are to be read as covering the full scope of
30 the invention as is implicit within the invention and the disclosure that has been provided herein.

I CLAIM:

1. An electronic air cleaner for removing dust from an arriving air flow comprising:
 - 5 (a) polarizable, air-permeable trapping medium for collecting dust particles,
 - (b) a plurality of alternately, differentially charged polarizing electrodes having surfaces and edges that are aligned to permit air flow to arrive edge-on and to pass therebetween; and
 - 10 (c) a source of electrical potential connected to supply charge to the polarizing electrodes and provide a polarizing potential therebetweenwherein said medium is positioned between said polarizing electrodes to cause said trapping medium to become polarized
15 and to trap dust particles from air flow passing between the polarizing elements.
2. An electronic air cleaner as in claim 1 wherein said medium is removably installed between the polarizing electrodes for ease of replacement of said medium.
- 20 3. An electronic air cleaner as in claim 1 wherein said polarizing electrodes comprise a plurality of conductive plates that are aligned in parallel to each other.
4. An electronic air cleaner as in claims 1, 2 or 3 wherein said trapping medium is in the form of pleated panels.
- 25 5. An electronic air cleaner as in claim 1 wherein said polarizing electrodes are provided by sections of said medium which are rendered conducting.

6. An electronic air cleaner as in claim 5 wherein the trapping medium comprises pleated panels and a conductive coating is applied to a sequence of panels to provide said polarizing electrodes.
- 5 7. An electronic air cleaner as in claim 5 wherein the trapping medium comprises a fibrous, air-permeable dielectric material.
8. An electronic air cleaner as in claims 1, 2, 3, 5, 6 or 7 comprising ionizing to introduce ions into an air flow
10 entering the trapping medium and increase the air cleaner's efficiency.
9. An electronic air cleaner as in claim 4 comprising ionizing to introduce ions into an air flow entering the trapping medium and increase the air cleaner's efficiency.
- 15 10. An electronic air cleaner as in claim 1 wherein the polarizing electrodes are aligned in parallel with the direction of the arriving airflow.
11. An electronic air cleaner as in claim 1 wherein the polarizing electrodes are aligned obliquely to the direction
20 of the arriving airflow.
12. An air filter cartridge for removing dust from an airflow comprising
- (a) polarizable, air-permeable trapping medium for collecting dust particles,
- 25 (b) a plurality of polarizing electrodes having surfaces and edges that are aligned to permit air

flow to arrive edge-on and to pass therebetween;
and

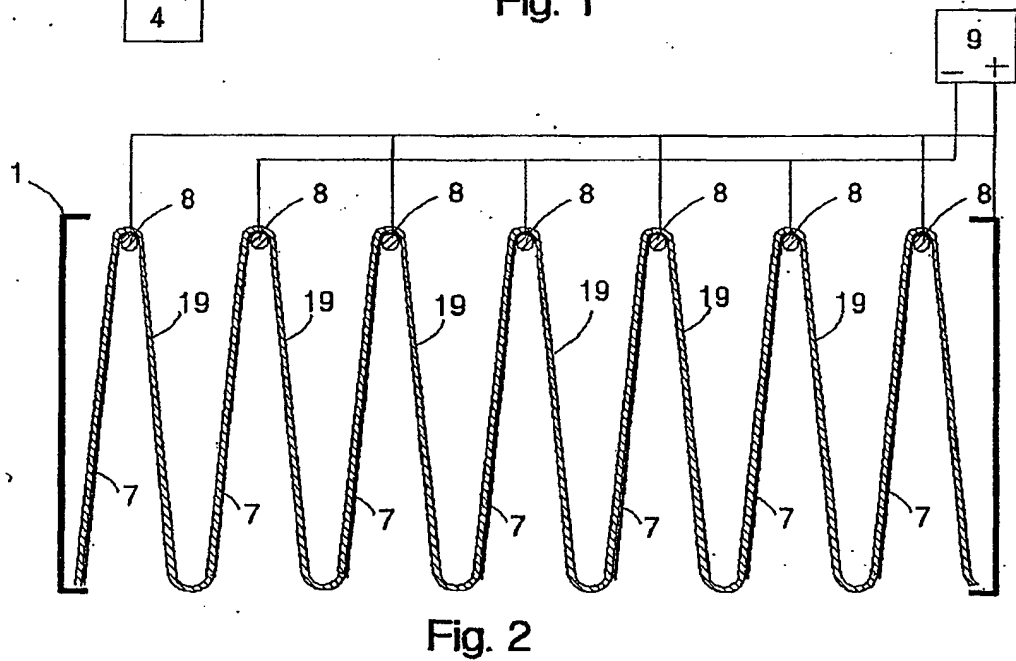
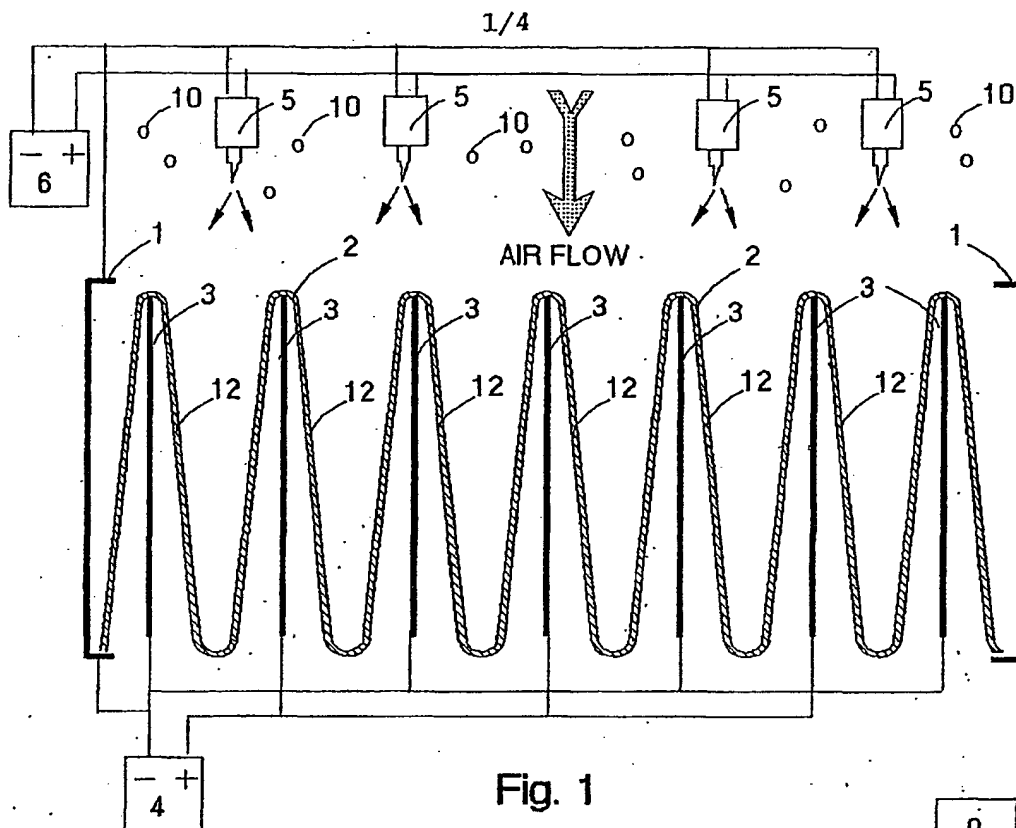
- (c) means for connecting the polarizing electrodes to a source of electrical charge and provide a polarizing potential therebetween
- 5 wherein said medium is positioned between said polarizing electrodes to cause said trapping medium to become polarized and to trap dust particles from air flow passing between the polarizing elements.

10 13. A cartridge as in claim 1 wherein the trapping medium is in the form of pleated panels, sections thereof being conductive to provide said polarizing electrodes.

14. A cartridge as in claim 1 wherein the trapping medium is in the form of a series of polarizable, fibrous

15 media interleaved between said polarizable electrodes.

15. A cartridge as in claim 14 wherein the polarizing electrodes are provided by layers of flexible conductive sheets interspersed between the fibrous media.



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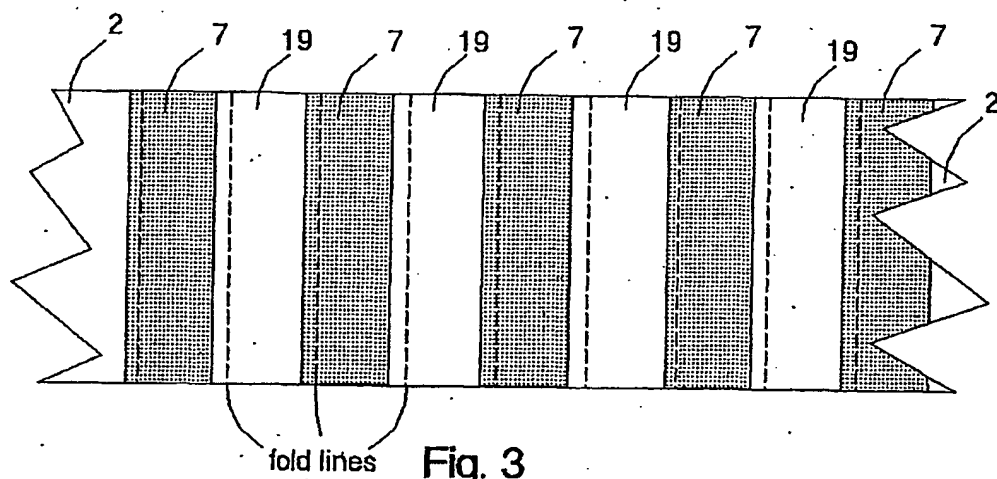


Fig. 3

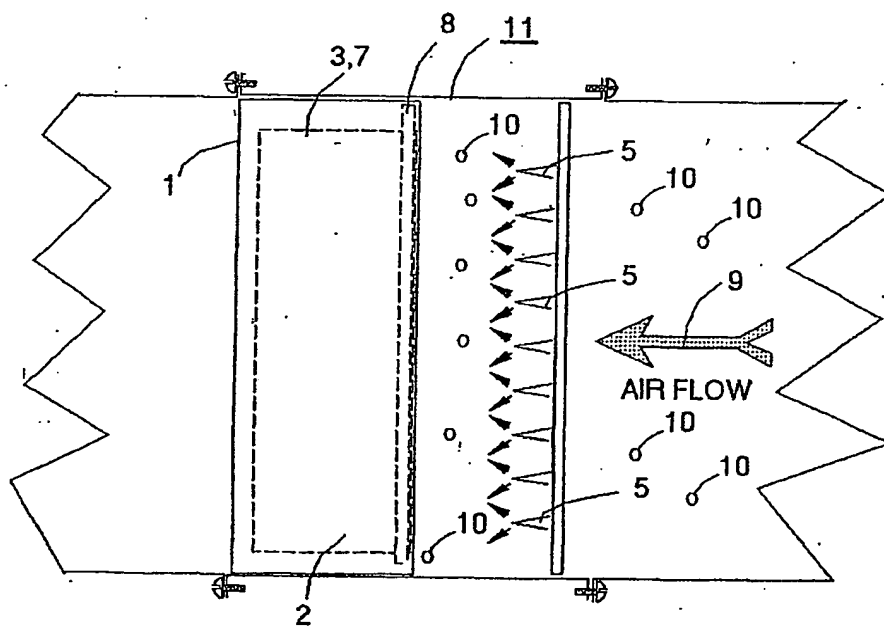


Fig. 4

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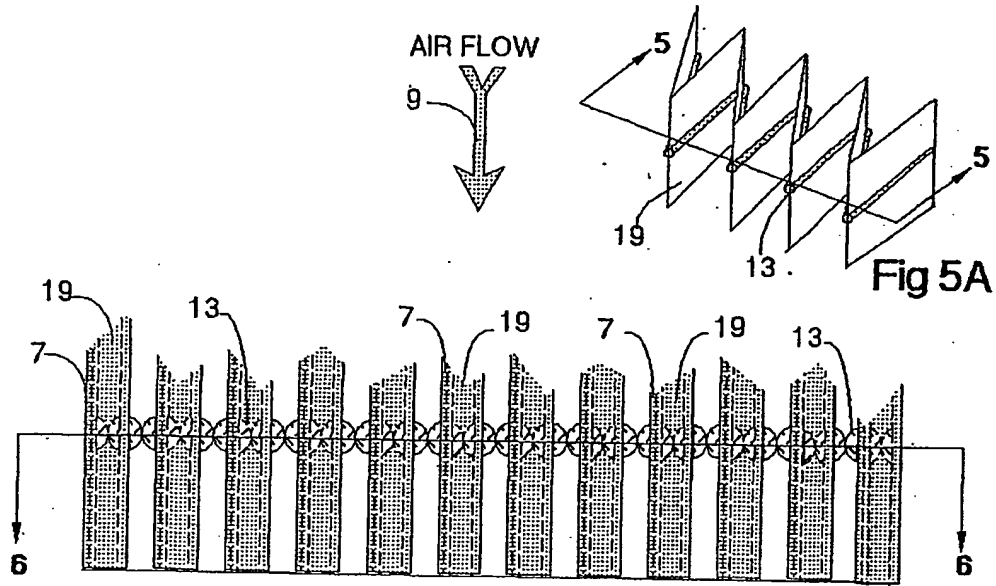


Fig. 5

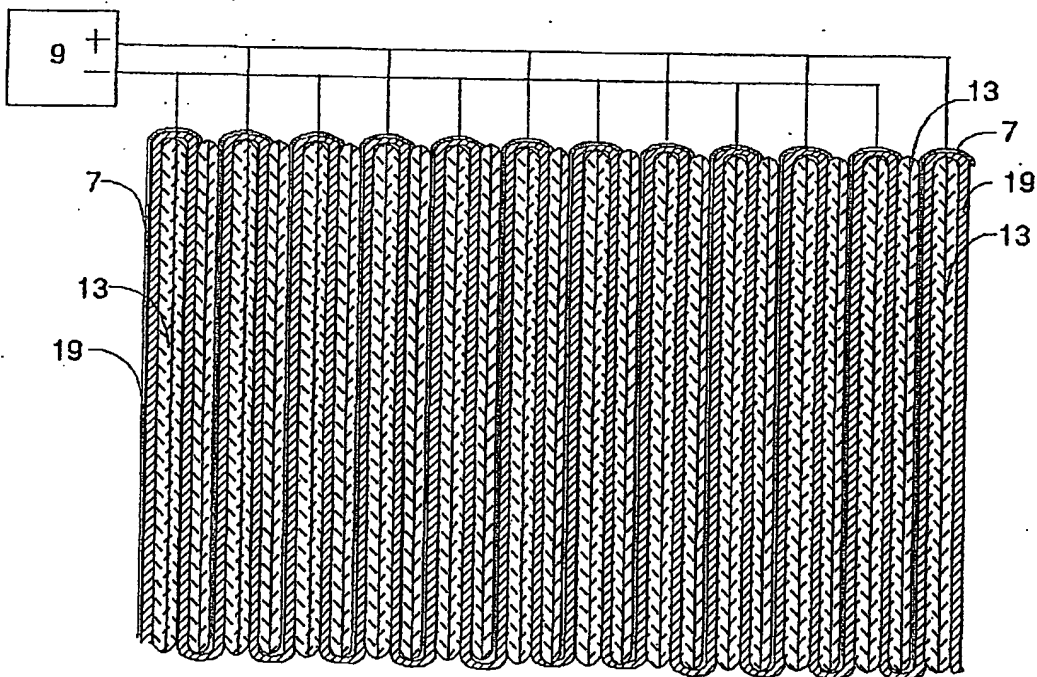


Fig. 6

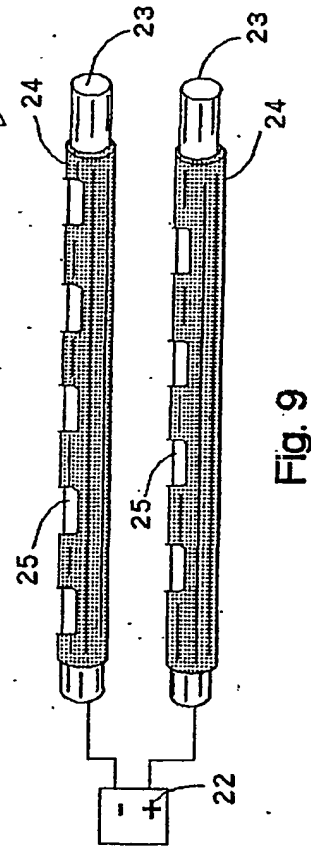
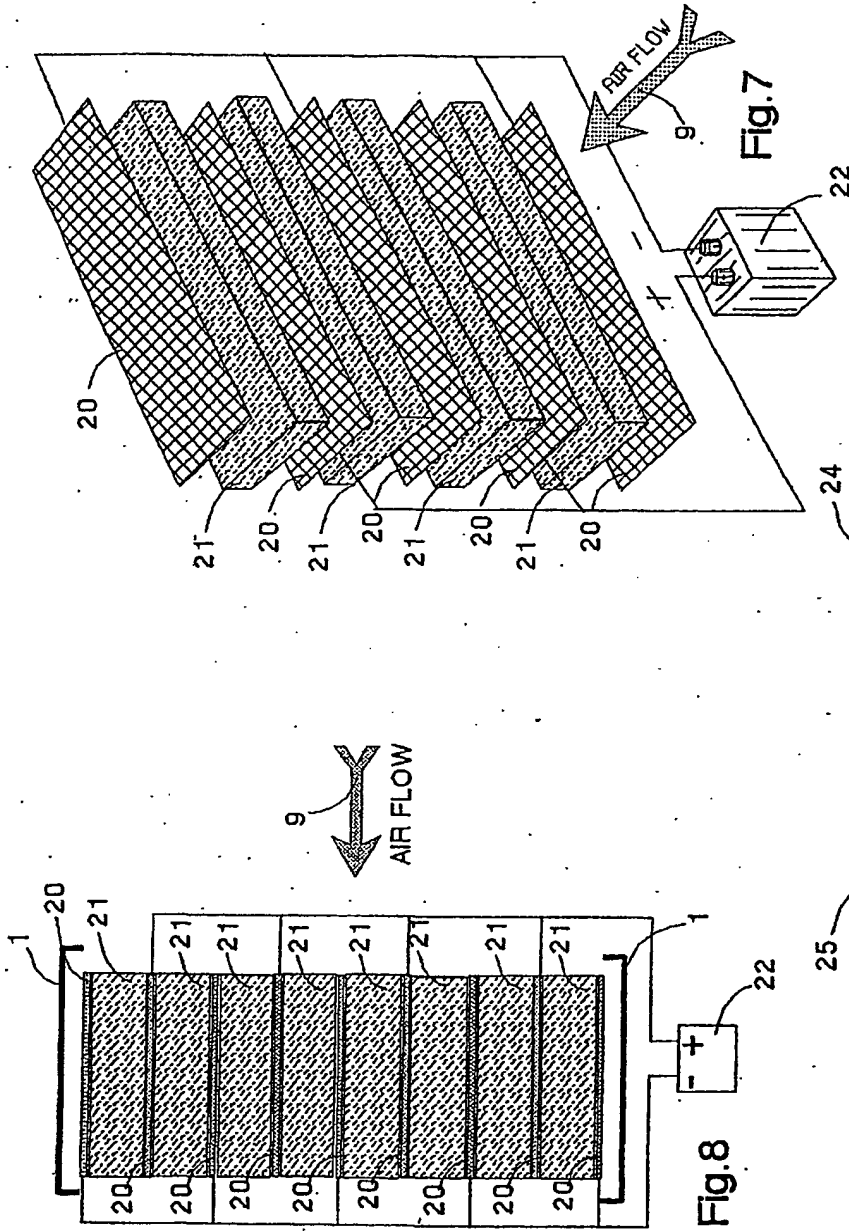


Fig. 9

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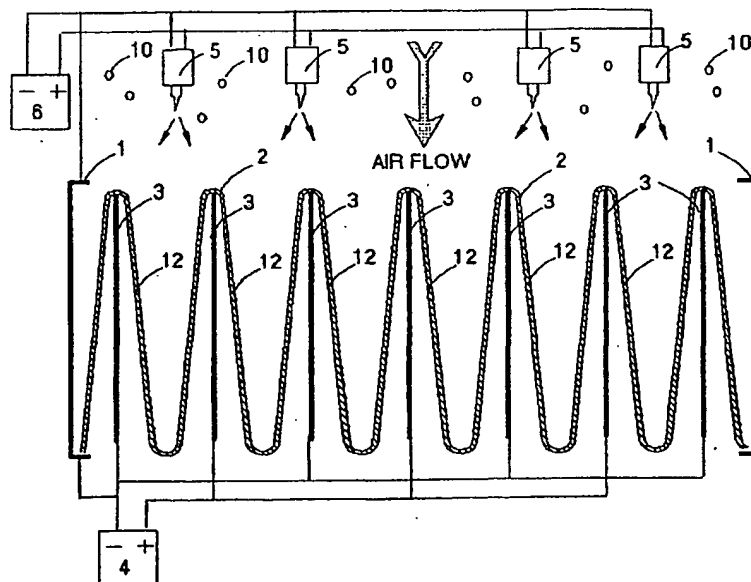
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Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☐ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

3 April 2002

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INTERNATIONAL SEARCH REPORT
 information on patent family members

Int'l Application No
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